Micro-Feasibility Study

Low-carbon Horticulture at N&N Mason Site in Lincolnshire

Commissioned by the Midlands Net Zero Hub
March 2022
Jenna Barnard
District Eating Ltd

Terms and Conditions

This report is limited to the early-stage outline feasibility and scoping of potential for development of a greenhouse utilising waste heat. The numbers and additional details included in this piece of work are estimations only, to be refined at later stages of project development.

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The information contained in this report is based on assumptions and the best available information at the time of writing. Assumptions will be based on a combination of rules of thumb, best estimates, referenced sources, and selected equipment suppliers. The yield, price and cost estimates and analysis are to be used for guidance purposes only. This report is a high-level initial assessment to be followed up with the items listed in the Next Steps section.

Executive Summary

This project was commissioned by the Midlands Net Zero Hub to assess the potential for low-carbon horticulture using waste heat from biomass boilers at a farm in North Lincolnshire.

Site Review and Crop Selection

The available site is 1.5 Ha, with the potential to expand in the future up to 4.5Ha. District Eating Ltd (DEL) selected organic tomatoes as the most suitable crop based on their high market value.

Heat and Power Demand

The estimated heat and power demand for a 1.5Ha heated greenhouse with LED lights producing organic tomatoes were 11,210,245 kWh and 5,098,365 kWh per year respectively.

Financial Viability

DEL estimated capital costs, operational costs, income of the greenhouse and income to the heat producer. Assumptions are shown throughout the report and in the Appendix. Two scenarios were modelled, outlined in the following table.

Table 1: Scenarios considered in outline techno-economic modelling.

Scenario 1	The client does not install additional biomass capacity. Back-up heat is from kerosene. Electricity is from the grid.
Scenario 2	The client invests in additional biomass CHP to supply the entire heat and power demand of the greenhouse.

Capital cost was estimated to be £4,594,615, with the cost of the glasshouse and lighting likely to be the biggest capital expense. Operational costs (OpEx) in Scenario 1 were estimated at £2,843,783. In Scenario 2, total OpEx is estimated at £2,010,243. The biggest costs arise from labour, electricity and heat.

Financial viability of the two scenarios is summarised in the following table.

Table 2: Financial viability of greenhouse.

	Scenario 1*	Scenario 2**
Greenhouse CapEx	£4,594,615	£4,594,615
Greenhouse Annual OpEx	£2,843,783	£2,010,243
Greenhouse Annual Income	£2,919,000	£2,919,000
IRR of Greenhouse	-9%	19%
PayBack of Greenhouse (years)	0.00	5.06
NPV of Greenhouse @ 20 years	-£3,090,281	£13,580,527

*Primary heat source £0.03/kWh, back-up heat £0.045/kWh, electricity £0.20/kWh
**All heat £0.03/kWh, electricity £0.12/kWh

Potential income to the heat producer for the two scenarios is summarised in the following table.

Table 3: Potential income to heat and power producer.

	Scenario 1*	Scenario 2**
Income from selling heat	£156,965	£336,307
Income from selling power	-	£504,000
Income from additional RHI	-	£152,590
Total Income	**£156,965**	**£992,897**

*Primary heat source £0.03/kWh, back-up heat £0.045/kWh, electricity £0.20/kWh
**All heat £0.03/kWh, electricity £0.12/kWh

Carbon Savings

DEL estimated that in Scenario 1, organic tomatoes would have higher emissions than business as usual. However, in Scenario 2, carbon savings of up to 78% compared to business as usual could be possible, provided that a proportion or all of the electricity used is from renewable or low-carbon sources.

Conclusions and Recommendations

- There is potential for an attractive business case for both the grower and the heat producer for a 1.5 Ha greenhouse producing organic tomatoes, with heat supplied by biomass boilers and a proportion of electricity provided by CHP and solar PV.
- Growing organic tomatoes increases the market value and makes a better economic case for a greenhouse, especially at 1.5 Ha. Organic production differs from conventional production because it restricts the use of chemical pesticides and herbicides. As such, growing organically may result in lower yields and higher labour demand. This was factored into the outline techno-economic modelling.
- Further feasibility work should consider the use of animal and plant manures to supplement compost and potentially reduce operational costs.
- To create the best business case, the client should increase heat output so they can provide both primary and back up heat to the greenhouse. They can do this by investing in another second-hand biomass boiler. This would allow them to earn them more money via sale of heat and RHI subsidies. It would also make the greenhouse more profitable as it would be able to buy heat at a lower price.
- Due to its high electricity demand, the greenhouse business case is sensitive to electricity prices. With current increases in electricity prices, the greenhouse could be vulnerable if relying on grid electricity. It is therefore recommended that the heat and power producer increase renewable electricity generation to supply a greater proportion of the greenhouse's electricity demand.
- For the organic tomatoes to be less carbon intensive than business as usual production, it is essential that the greenhouse is supplied via a renewable electricity tariff for at least a proportion of its energy requirements. Further feasibility work should conduct a sensitivity analysis to find out what proportion of electricity must be generated by renewable sources for the produce to result in carbon savings. DEL recommends consideration should be given to the following options that could be used to supply a greenhouse with renewable or low carbon power:

    - Switching to a 100% renewables tariff,
    - Installing biomass CHP, providing the biomass is from a sustainable source,
    - Installing onsite renewables such as wind, solar, or anaerobic digestion

  Taking these measures would reduce carbon footprint of the produce grown in the greenhouse.

Next Steps

The recommended next steps if the client wishes to pursue this project are as follows:

- Share this work with key stakeholders. Meet and discuss key benefits.
- Meet with District Eating to discuss how to proceed for maximum benefit to the client and other key stakeholders.
- Decide on preferred commercial option for delivery as explained in the Work Package 2 Report.
- Review funding opportunities and apply for funding for feasibility study and capital costs, including consideration of who will pay for connection to the heat source.
- Investigate planning permission of the site and surrounding land.
- Conduct a flood risk assessment and land stability assessment of the site.
- Conduct a full detailed feasibility study to include an investment grade business case (IGBC) that also includes:
    - A market research study of tomatoes including statement of interest from buyers.
    - Modelling of a greenhouse and revised estimated heat demand.
    - An evaluation of how best to use the land around the greenhouse.
- Confirm the potential amount of heat and power that are available in high level of detail.
- Conduct further research into the organic certification process, including a soil analysis and projections of how long it will take to achieve organic status.
- Conduct market research to confirm buyers for organic tomatoes. This could include discussions with local councils to discuss procurement for local school dinners.
- Investigate potential to maximise growing space by growing an additional winter salad crop.
- Take advantage of gaps in the market, for example cuttings are currently imported from Holland. This could be something to investigate to create a diverse business plan.

Table of Contents

Executive Summary ***3***

Site Review and Crop Selection 3

Heat and Power Demand 3

Financial Viability 3

Carbon Savings 4

Conclusions and Recommendations 4

Next Steps 5

1.0 Site Review ***7***

1.1 Proposed Heat Source 7

1.1.1 Potential for Expansion 7

2.0 Greenhouse Sizing and Crop Selection ***8***

2.1 Organic Agriculture 8

2.2 Certification & UK Control Bodies 8

2.3 Heat Demand Estimate 9

2.3 Power Demand Estimate 9

2.4 Scenarios for Consideration 10

3.0 Outline Techno-Economic Modelling ***10***

3.1 Capital Costs 11

3.2 Operational Costs 11

3.3 Income – Grower 11

3.4 Income – Heat and Power Producer 12

3.5 Financial KPIs 12

3.6 Sensitivity Analysis 13

4.0 Carbon Savings ***14***

5.0 Conclusions and Recommendations ***15***

6.0 Next Steps ***15***

Appendix 1: Assumptions ***17***

1.0 Site Review

The selected site is a farm in rural North Lincolnshire, owned by an innovative and diverse small business. The company produces woodchip, 25% of which is used onsite in three biomass boilers, and the rest of which is sold to nearby customers. The company also runs a business which works closely with refurbished second-hand biomass boilers, which still have years left of Renewable Heat Incentive (RHI) subsidies. There is a 4.5 Ha field immediately beside the heat source which is the proposed site for a greenhouse. The client is willing to initially commit 1.5 Ha to a horticultural development, with the potential to expand up to 4.5 Ha in the future if the business case is attractive. The site consists of grass and stubble which is flat and uncontaminated. Access to the site is via a narrow, unpaved road. Accessibility and parking for large vehicles could pose a challenge at this site.

Figure 1: Map showing land available for low carbon horticulture.

1.1 Proposed Heat Source

Heat is currently generated via three biomass boilers. The maximum heat capacity of the three boilers at the site is 1.3MW, some of which is used to dry woodchip. Currently an estimated 1MW could be available for a horticultural project. Around 60kW electricity is generated onsite from a solar photovoltaic installation. Currently around 25% of this is sold to the grid.

1.1.1 Potential for Expansion

The company has a combined heat and power (CHP) unit on another site which could potentially be moved to this site, which could add an estimated additional 75kW electricity and 200kW heat generation. The client's business includes production of woodchip and selling refurbished second-hand biomass boilers that still have years left of RHI subsidies. There is therefore potential to expand heat and power production relatively easily and cheaply as the client has access to refurbished biomass boilers and wood pellets.

2.0 Greenhouse Sizing and Crop Selection

The proposed site is large enough for a 4.5 Ha greenhouse, and with the potential to add a CHP unit or a biomass boiler, heat and power production are not limiting factors. Commercial greenhouses are generally built at scale, typically around 5 hectares or more. This is due to the economics of scale, expensive capital costs, and the low sale price of fruit and vegetables. Smaller greenhouses can be profitable if crops are selected carefully to maximise value. For example, if a proportion or all of the greenhouse is used to produce cash crops this can supplement the income of the greenhouse.

The client is willing to commit 1.5 Ha initially to a horticultural development. As mentioned, this is likely to be too small for conventional horticulture to be financially viable. Therefore, DEL decided to investigate production of organic tomatoes. Organic produce has a higher market value, so can be financially viable in a smaller greenhouse. DEL understand that there is a lack of organic growers in the UK, and demand is high.

2.1 Organic Agriculture

Organic food is the product of farming systems which avoid the use of man-made fertilisers, pesticides, growth regulators and livestock feed additives. Irradiation and the use of genetically modified organisms (GMOs) or products produced from or by GMOs are generally prohibited by organic legislation. Most certifying bodies require that crops are grown in soil, as opposed to hydroponics or containers. Organic agriculture is a systems approach to production that is working towards environmentally, socially and economically sustainable production. It places emphasis on agricultural systems that rely on crop rotation, animal and plant manures, some hand weeding and biological pest control. Organic status reflects that farming practices focus on feeding the soil rather than the plants.

2.2 Certification & UK Control Bodies

To be certified as an organic producer you must be registered with an organic control body. There are currently six approved organic control bodies in the UK, the details of which are listed below. Each control body has a conversion process which they use to guide growers through the transition to organic status. It typically takes two years to become certified as an organic producer but this can be shorter depending on how the soil has previously been managed. Produce can be labelled as "product under conversion to organic farming" once 12 months of the certification period have lapsed.

Table 4: Organic certifying bodies and contact information.

Control Body	Website	Telephone No.	Email
Organic Farmers and Growers CIC	www.ofgorganic.org	01939 291800	info@ofgorganic.org
Organic Food Federation	www.orgfoodfed.com	01760 720444	info@orgfoodfed.com
Soil Association Certification Ltd	www.soilassociation.org/certification/	0117 914 2412	prod.cert@soilassociation.org

Biodynamic Association Certification	www.bdcertification.org.uk	01453 766296	certification@biodynamic.org.uk
Quality Welsh Food Certification Ltd	www.wlbp.co.uk	01970 636688	info@wlbp.co.uk
OF&G (Scotland) Ltd	www.ofgorganic.org	01939 291800	certification@sopa.org.uk

2.3 Heat Demand Estimate

DEL conducted modelling using local climate data and assumptions for growing temperatures required by tomatoes to generate peak and annual heat demand for 1.5 Ha of production. The model used the approximate size of the existing heat source (1MW) to estimate how much greenhouse heating would come from the biomass boilers, and how much would come from a back-up source. The most pragmatic option for a back-up heat source would be to use the existing CHP on the client's other site, or an additional biomass boiler, as previously mentioned.

Table 5: Heat demand for 1.5 Ha of tomatoes

	Tomatoes
Peak (kW)	4,735
Heat Required (kWh/year)	11,210,245
Heat from primary source (kWh/year)	5,232,166
Heat from back-up source (kWh/year)	5,978,078

2.3 Power Demand Estimate

Electricity demand and consumption were estimated based upon the following assumptions:

- Pump mechanical power was derived from the mechanical power required to deliver flow rate required to deliver heat in any given hour which was then transformed into electrical power input accounting for efficiency losses from wire to water. Overall pump–motor efficiency was assumed to be 62.6% (example from Grundfos pump selector),
- Water requirement for conventionally grown tomatoes assumed to be 10 litres per kg.
- Air circulation fans: Horizontal distribution 10 units per hectare, 150W, costing £500 each.
- Lighting: Cost and specification information for Arize Element L1000 LED lighting was obtained and used to estimate energy use for lighting the greenhouse.

Based upon these assumptions the annual electricity consumption was estimated to be approximately **5,098,365 kWh per year.**

2.4 Scenarios for Consideration

The heat and energy demand of a greenhouse is high, and therefore heat and power are likely to be expensive. Given recent increases in electricity costs and volatile energy markets, relying on fossil fuels for back up heat and grid electricity for power will make it difficult to create a business case that is financially viable. It is therefore strongly recommended that the client invests in additional biomass CHP capacity to supply the greenhouse with cheap, reliable and renewable heat and power.

To illustrate this, two scenarios are considered in the outline techno-economic modelling:

Table 6: Scenarios for consideration in techno-economic modelling.

Scenario 1	The client does not install additional biomass capacity. Back-up heat is from kerosene. Electricity is from the grid.
Scenario 2	The client invests in additional biomass CHP to supply the entire heat and power demand of the greenhouse.

Table 7: Heat and electricity prices assumed in techno-economic modelling

	Scenario 1	Scenario 2
£/kWh Primary Heat	0.03	0.03
£/kWh Back-up Heat	0.045	0.03
£/kWh Electricity	0.20	0.12

IMPORTANT NOTE: This work was carried out from January 2022 – March 2022, a time of extremely volatile energy prices. At the time of writing, energy prices were rising steeply, and food prices had not yet caught up with this. Therefore, it was difficult to make realistic assumptions about electricity prices and produce sale prices that reflected these rapid changes and the changes to come over the next 6 months. The prices used here are illustrative prices that will need reviewing and updating at the next stage of the project.

3.0 Outline Techno-Economic Modelling

This section details the methodology and results of the techno-economic modelling done by DEL. The methodology is summarised as follows:

1. Capital cost estimation,
2. Operational cost estimation for power, heat, water and nutrients, seedlings and bulbs, compost, labour, insurance, and repairs and maintenance,
3. Income estimation for flowers and crops,
4. Completion of 20-year cash flow (not adjusted for inflation),
5. Estimation of simple payback, NPV, IRR, and NPV @ 20 years.

3.1 Capital Costs

Capital expenditure (CapEx) was estimated. The model assumed that tomatoes are grown conventionally in soil enriched with compost. The cost of the glasshouse and the lighting are expected to be the biggest capital expenses of the project. While purchasing multi-span polytunnels may reduce capital costs, they are typically less energy efficient, do not offer the same opportunities to control the environment, have a higher heat loss coefficient than glass, RHI cannot be paid for heat sold into them, and they can be less robust than glass so may not offer the same longevity.

For this study, budget estimates for the cost of a 1.5 Ha glasshouse structure were gathered from two reputable greenhouse supplier companies. One supplier provided an approximate price for a second-hand glasshouse. Second-hand greenhouses offer a chance to reduce capital costs but can present issues such as increase cost of maintenance. Due diligence checks must be made carefully to ensure frame quality is suitable for the location and local weather conditions, and that the building is insurable. Due to the potential for lower capital costs, a second-hand greenhouse was selected over purchasing a new glasshouse in the techno-economic modelling. This decision needs evaluating in future feasibility and business case work.

Based on outline quotations from greenhouse suppliers, the cost of a 1.5 Ha second-hand glasshouse with screening would be around £1,143,000 including VAT. Addition costs to factor in include LED lights, heating infrastructure, electrical and control infrastructure, preliminaries, and contingency. A concrete pad and benching are not required as tomatoes will be grown organically in the ground.

The total estimated CapEx is £4,594,615. This CapEx figure is a high-level estimate only that will vary depending on many variables and should be refined at a later stage in the project.

3.2 Operational Costs

Operational expenses (OpEx) were estimated. OpEx is expected to include electricity, heat, water and nutrients, seedlings and bulbs, compost, labour, insurance, and repairs and maintenance. Prices of resource inputs were estimated using benchmark costs per unit, growing space area, and crop profiles. Labour cost is an important part of OpEx. DEL assumed that the greenhouse would require 3 full-time skilled growers, a full-time greenhouse manager, and 4 full time apprentice crop technicians. Electricity and heat make up a large proportion of OpEx.

In Scenario 1, where back up heat is from kerosene and electricity is from the grid, total OpEx is estimated at **£2,843,783** per year. In Scenario 2, where all heat and power are supplied from the client's biomass CHP, total OpEx is estimated at **£2,010,243** per year.

3.3 Income – Grower

Income was estimated using wholesale prices, crop yields, and area of growing space. Wholesale prices (£/kg) for organic tomatoes were obtained from the Soil Association, and an average for 2019-2021 was calculated. It is important to note that wholesale prices fluctuate on a weekly, monthly, and seasonal basis, and between different types of tomatoes. A detailed feasibility study should include market research to model the potential impacts of seasonally fluctuating prices on the overall economics of the greenhouse, as well as to ensure a market for the produce.

Based on our assumptions, the total annual income of a 1.5 Ha greenhouse producing organic tomatoes was **£2,919,000**. This is based on assumptions of crop spacing, yield, cropping cycles, and sale prices that need refining at the next stage of the project.

3.4 Income – Heat and Power Producer

In Scenario 1, the heat producer generates income selling their existing waste heat into the greenhouse. In Scenario 2, they install additional capacity with biomass CHP, enabling them to supply the greenhouse with power and back up heat. If using second hand boilers on the RHI scheme, they can also claim additional RHI subsidies. Generating an additional 5,978,078kWh per year to cover the back-up heat demand would earn the generator an estimated £152,590 per year through RHI subsidies[1]. This could enable the heat generator to sell heat to the greenhouse at a lower price per kWh.

This is summarised in the table below.

Table 8: Potential income to heat and power producer.

	Scenario 1*	Scenario 2**
Income from selling heat	£156,965	£336,307
Income from selling power	-	£504,000
Income from additional RHI	-	£152,590
Total Income	**£156,965**	**£992,897**

*Primary heat source £0.03/kWh, back-up heat £0.045/kWh, electricity £0.20/kWh
**All heat £0.03/kWh, electricity £0.12/kWh

3.5 Financial KPIs

The results of the techno-economic modelling are summarised in the table below, for both Scenario 1 and Scenario 2. Results indicate that the project is not financially viable if using grid electricity. For a profitable business case, the greenhouse will need to be supplied with lower cost heat and power from biomass CHP.

[1] Tier 1 tariff of 3.17p available for 35% of generation, additional covered by Tier 2 tariff of 2.22p. Guidance available here: https://www.ofgem.gov.uk/publications/non-domestic-rhi-main-guidance

Table 9: Financial KPIs of greenhouse.

	Scenario 1*	Scenario 2**
Greenhouse CapEx	£4,594,615	£4,594,615
Greenhouse Annual OpEx	£2,843,783	£2,010,243
Greenhouse Annual Income	£2,919,000	£2,919,000
IRR of Greenhouse	-9%	19%
PayBack of Greenhouse (years)	0.00	5.06
NPV of Greenhouse @ 20 years	-£3,090,281	£13,580,527

*Primary heat source £0.03/kWh, back-up heat £0.045/kWh, electricity £0.20/kWh
**All heat £0.03/kWh, electricity £0.12/kWh

3.6 Sensitivity Analysis

Financial KPIs are shown across a variety of heat and power sale prices, demonstrating different scenarios that could be negotiated between the heat seller and the grower. The analysis indicates that the business case is **fairly sensitive** to heat prices but **very sensitive** to electricity prices. This shows again how vulnerable the business case could be to increasing electricity prices if dependent on grid electricity, emphasising the need for additional biomass CHP on the site if the project progresses.

Table 10: Sensitivity Analysis showing greenhouse KPIs at various heat prices.

Heat price per kWh	£0.01	£0.02	£0.03	£0.04
IRR of greenhouse	24%	22%	19%	17%
PayBack of greenhouse	4.06	4.50	5.06	5.77
NPV of greenhouse @ 20 years	£18,064,625	£15,822,576	£13,580,527	£11,338,479

Electricity price held constant at £0.12/kWh

Table 11: Sensitivity Analysis showing greenhouse KPIs at various electricity prices.

Electricity Price per kWh	£0.12	£0.16	£0.20
IRR of greenhouse	19%	10%	-3%
PayBack of greenhouse	5.06	8.56	0.00
NPV of greenhouse @ 20 years	£13,580,527	£6,141,835	-£1,296,857

Heat price held constant at £0.03/kWh

4.0 Carbon Savings

The potential carbon savings were compared for the two scenarios and business-as-usual production of organic tomatoes in a greenhouse heated using gas. The high energy use from lighting the greenhouse means that in Scenario 1, when back up heat is from kerosene and 100% of electricity use is from the grid, the organic tomatoes produced in the proposed greenhouse have higher CO_2 emissions than the business-as-usual scenario. However, in Scenario 2 where all heat and electricity are supplied by biomass CHP, the production of organic tomatoes results in a carbon saving of 78% compared to business-as-usual.

Table 12: Carbon savings of proposed greenhouse scenarios compared to business-as-usual.

	Scenario 1	Scenario 2	Business As Usual
CO2 emissions per kg tomatoes	5.17kg	0.47kg	2.1kg*
CO2 emissions per year for 1.5Ha greenhouse	2,714 tonnes	247 tonnes	1,103 tonnes

*Business-as-usual carbon emissions of organic tomatoes from a life cycle analysis study of organic and non-organic tomatoes grown in a heated greenhouse in the Netherlands[2].

A sensitivity analysis was performed on different proportions of grid and low carbon electricity, using 2021 emissions factors. Table 11 shows that if even 25% of electricity use is from low carbon sources, carbon savings of 9.2% can be achieved.

Table 13: CO_2 savings of organic tomatoes grown in proposed greenhouse compared to organic tomatoes grown in a greenhouse heated by gas in the Netherlands.

		% Grid electricity / % Low Carbon electricity				
		100%/0%	75%/25%	50%/50%	25%/75%	0%/100%
CO_2 emissions: Business as Usual*	kg CO_2/kg crop	2.1	2.1	2.1	2.1	2.1
CO_2 Emissions: Proposed greenhouse	kg CO_2/kg crop	2.39	1.91	1.43	0.95	0.47
Carbon savings	%	-14%	9%	32%	55%	78%
Total CO_2 emissions of proposed greenhouse	Tonnes/year	1252	1001	749	498	247

*Business as usual carbon emissions of organic tomatoes from a life cycle analysis study of organic and non-organic tomatoes grown in a heated greenhouse in the Netherlands[3].

[2] https://library.wur.nl/WebQuery/wurpubs/fulltext/158875
[3] https://library.wur.nl/WebQuery/wurpubs/fulltext/158875

5.0 Conclusions and Recommendations

- There is potential for an attractive business case for both the grower and the heat producer for a 1.5 Ha greenhouse producing organic tomatoes, with heat supplied by biomass boilers and a proportion of electricity provided by CHP and solar PV.
- If built, the greenhouse could provide a range of skilled employment opportunities, apprenticeships, and training opportunities for local people.
- If a proportion of CapEx were to be provided by grant funding, it could increase the IRR and reduce the payback time.
- Growing organic tomatoes increases the market value and makes a better economic case for a greenhouse, especially at 1.5 Ha. Organic production differs from conventional production because it restricts the use of chemical pesticides and herbicides. As such, growing organically may result in lower yields and higher labour demand. This was factored into the outline techno-economic modelling.
- Further feasibility work should consider the use of animal and plant manures to supplement compost and potentially reduce operational costs.
- To create the best business case, the client should increase heat output so they can provide both primary and back up heat to the greenhouse. They can do this by investing in another second-hand biomass boiler. This would allow them to earn them more money via sale of heat and RHI subsidies. It would also make the greenhouse more profitable as it would be able to buy heat at a lower price.
- Due to its high electricity demand, the greenhouse business case is sensitive to electricity prices. With current increases in electricity prices, the greenhouse could be vulnerable if relying on grid electricity. It is therefore recommended that the heat and power producer increase renewable electricity generation to supply a greater proportion of the greenhouse's electricity demand.
- For the organic tomatoes to be less carbon intensive than business as usual production, it is essential that the greenhouse is supplied via a renewable electricity tariff for at least a proportion of its energy requirements. Further feasibility work should conduct a sensitivity analysis to find out what proportion of electricity must be generated by renewable sources for the produce to result in carbon savings. DEL recommends consideration should be given to the following options that could be used to supply a greenhouse with renewable or low carbon power:
    - Switching to a 100% renewables tariff,
    - Installing biomass CHP, providing the biomass is from a sustainable source,
    - Installing onsite renewables such as wind, solar, or anaerobic digestion

  Taking these measures would reduce carbon footprint of the produce grown in the greenhouse.

6.0 Next Steps

The recommended next steps if the client wishes to pursue this project are as follows:

- Share this work with key stakeholders. Meet and discuss key benefits.
- Meet with District Eating to discuss how to proceed for maximum benefit to the client and other key stakeholders.
- Decide on preferred commercial option for delivery as explained in the Work Package 2 Report.

- Review funding opportunities and apply for funding for feasibility study and capital costs, including consideration of who will pay for connection to the heat source.
- Investigate planning permission of the site and surrounding land.
- Conduct a flood risk assessment and land stability assessment of the site.
- Conduct a full detailed feasibility study to include an investment grade business case (IGBC) that also includes:
    - A market research study of tomatoes including statement of interest from buyers.
    - Modelling of a greenhouse and revised estimated heat demand.
    - An evaluation of how best to use the land around the greenhouse.
- Confirm the potential amount of heat and power that are available in high level of detail.
- Conduct further research into the organic certification process, including a soil analysis, projections of how long it will take to achieve organic status, and cost analysis of compost and manure options.
- Conduct market research to confirm buyers for organic tomatoes. This could include discussions with local councils to discuss procurement for local school dinners.
- Investigate potential to maximise growing space by growing an additional winter salad crop.
- Take advantage of gaps in the market, for example cuttings are currently imported from Holland. This could be something to investigate to create a diverse business plan.

Appendix 1: Assumptions

Due to the broad scope of this initial micro-feasibility study, various assumptions were made in the techno-economic modelling. These serve as outline figures only and will need refining if the client proceeds with the project.

Table 14: Assumptions made in techno-economic modelling.

Figure	Value	Justification/Source
Cost per seedling	£0.50	Obtained from a horticultural expert.
Wholesale price (non-organic)	£1.39 per kg	Price from Brakes Wholesalers, minus 20% to account for wholesaler's profit margin.
Wholesale price (organic)	£5.56 per kg	Average prices for 2019-2021 from the Soil Association.
Yield (non-organic)	58kg per m^2 per year	Yields for heated greenhouse production of tomatoes reported here[4].
Yield (organic)	50kg per m^2 per year	Yields for organic production estimated here[4].
Cropping density	2.5 plants per m^2	Reported to give the best financial margin in North European conditions[5].

Carbon Factors

Carbon Factor	Unit	Value
Heat and power from Biomass	Kg CO_2e/kWh	0.01513
Grid Electricity	Kg CO_2e/kWh	0.21233

Source: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

[4] https://library.wur.nl/WebQuery/wurpubs/fulltext/158875

[5] https://www.cabi.org/ISC/FullTextPDF/2006/20063016915.pdf